of 655 days with thunderstorms in the 30 years, and the former 641. The number of days with thunderstorms has increased along the Mexican border, but the Pacific coast is still practically immune.

During the 7 months, January to July, inclusive, thunderstorm activity has been *increasing* both as to intensity and area covered. In August (fig. 8) we detect the first evidence of disintegration, as shown in the (as yet slightly) diminishing number of thunderstorm days along the Canadian border, and in the weakening of the secondary over the Southwest. However, the average is still high over the southern half of the country; the Pacific coast is nearly free from these phenomena, especially the northern California coast.

The most obvious fact revealed by the September chart (fig. 9) is that thunderstorm activity is rapidly diminishing over the entire country, unless it be along the Pacific coast where there seems to be a very slight increase. The two centers of activity, the primary over Florida and the secondary over northern New Mexico, still persist but both are now weakening rapidly; in fact, a strong secondary is now forming over the middle Mississippi Valley. There is little thunderstorm activity in September along or north of the Canadian border.

In October (fig. 10), the primary center that has been over Tampa for so long seems to have dropped south and is now over Key West, and the secondary is over the Arkansas-Oklahoma border, while a remnant of the erstwhile active secondary over New Mexico persists; but there has been a marked slowing-up of thunderstorm activity generally over the country, the storms being relatively most frequent in Florida and the southern Plains and lower Mississippi Valley States.

As is to be expected, the November chart (fig. 11) shows a still further diminution in thunderstorm activity and in the area covered; in fact the thunderstorm is now relatively rare in all parts of the country, the region of greatest frequency being the Ohio and lower Mississippi Valleys. Both the Florida and the southwest centers have practically disappeared, and the interior portions of the Atlantic States from Georgia to Maine are now almost immune.

The December chart (fig. 12) again reveals the center of greatest thunderstorm activity over northern Louisiana, and very little activity outside of the lower Ohio, lower Mississippi and the Gulf States.

This brings us to the conclusion of the whole matter, namely, a consideration of the annual chart (fig. 13). This chart shows the total number of days with thunderstorms at a large number of stations for the past 30 years (1904–33); it brings out very conspicuously the two great centers of activity, one over Tampa, Fla., and the other over Santa Fe, N. Mex. It is interesting to note that the average number of days with thunderstorms at Tampa is exactly the same, 94, for the 20-year and the 30-year records; the average at Santa Fe for the 20-year record was 73 and for the 30-year record 72; these facts substantiate somewhat the statement in the concluding sentence of the first paragraph of this article, namely, that these charts give *trustworthy* averages. One lesson to be drawn from the annual chart is that no part of the United States is entirely free from thunderstorms. The fact that the topography of Tampa differs so materially from that of Santa Fe introduces some interesting considerations. Tampa is at sea level and Santa Fe 7,013 feet above sea level.

In conclusion, the writer wishes to thank the Chief of the Weather Bureau for permission to gather the data for this paper, and the numerous officials in charge of the stations for supplying them. Through the courtesy of the Meteorological Service of Canada, data from Canadian stations near the border have been used in the present paper.

THE PENNSYLVANIA FIREBALL OF FEBRUARY 27, 1935

By CHARLES P. OLIVIER

[Flower Observatory, Upper Darby, Pennsylvania, May 1935]

At 6:20 p. m., eastern standard time, February 27, 1935, a fine fireball was seen to fall over Pennsylvania. Efforts to obtain reports of observations were at once made through the newspapers and otherwise. As the body appeared while twilight was still too bright for stars to be visible, good positions were reported only because the planet Venus was in the same part of the sky as seen from eastern Pennsylvania in general. The phenomenon attracted further attention because of the long-enduring train which was left.

In all, 16 observations were reported, as given in table 1. All 16 were concentrated in the sector from northeast to east of the path of the object. It was unfortunately impossible to get any reports from south, west, or north, though the fireball must have been visible from those directions. Seven of the observations received were available for the determination of the height of the upper end of the train, and five for the lower end. It is probable that the body itself was visible considerably higher, but all the observations obviously refer to the upper end of the train.

TABLE 1

No.	Station	Observer	Color	Duration (seconds)	Duration of train (minutes)
1	Glenolden, Pa	F. W. Smith	Y-W	1±	12
2	Pottsville, Pa	J. D. Smith	Y		4
3	Philadelphia, Pa	W. R. Brown		1−	15
4	Philadelphia, Pa	F. F. James		1−	2+
5	Devon, Pa	E. A. Skilton			
6	Philadelphia, Pa	E. Udell		<6	10
7	Allentown, Pa	C. H. Hoffman	Y		5
8	Magnolia, N. J	Mrs. E. J. Schmidt			
9	Glenside, Pa	Mrs. H. P. Camden			2+
10	Philadelphia, Pa	N. Mendelsohn			
11	Wynnewood, Pa	Mrs. Rose E. McCarthy			12
12	Paoli, Pa	J. B. Patton			
13	Reading, Pa	H. E. Hathaway	B-R-Y	1+	9+
14	Reading, Pa	S. Lash	Y	1−	5+
15	Mehoopany, Pa	W. R. English	Y-R	<5	20-25
16	Rutherford, N. J	W. F. Miner	O-Y	2	8

The data given in table 2 were calculated from the observations. As Venus was most fortunately at the right altitude as well as the right azimuth, to serve as a reference point, we may have confidence in the geo-

A typical fireball train, March 24, 1933. (*Upper*, near Dalhart, Tex., Bert D. Latham. *Lower*, Timpas, Colo., C. R. West.)

graphical location of the end point in spite of the distribution of observing stations; and as the path was nearly vertical there can be little more error in the location of the beginning point.

TABLE 2

Date: 1935 February 27, 6:20 p. m., eastern standard time.
Sidereal time at end point: 69°10′.
Ended over: $\lambda=77°41'$, $\varphi=+40°11'$.
Height at beginning of train: 61.7±7.8 km.
Height at end of train: 31.1±3.3 km.
Length of path: 30.9 km.
Radiant (uncorrected): $\begin{cases} a=233° \\ h=82° \end{cases}$
Radiant (corrected): $\begin{cases} a=233° \\ h=81° \end{cases}$ $\begin{cases} \alpha=79°.5 \\ \delta=+45°.7 \end{cases}$
Velocity of train drift (minimum) at 62 km: 121 km/hr.
Velocity of train drift (minimum) at 29 km: 79 km/hr.

The fireball itself was considerably brighter than Venus; and the duration of the train was certainly 12 minutes or more. Several drawings of the train were sent in, all showing most clearly that from a straight line at the beginning, almost vertical but sloping slightly from north to south (the angle as seen from due east was 85°), it gradually took the form of a zigzag line with two major projections, one at the top and one at the bottom. F. W. Smith at Glenolden, a trained meteor observer, plotted the train to scale on a star map, and our calculated velocities of drift depend on his drawing. The other reports were most useful in confirming the direction of the upper and lower drifts, and in very roughly confirming their values. Unfortunately, lacking any similar drawing made from a station more or less at right angles to his, we can deduce only the *projected* and therefore *minimum* drift. There is some reason to think, from a study of all the accounts and drawings, that for this train the drift was actually to north or south, so that these minimum figures are approximately the true ones.

Smith's drawings, made with the aid of an opera glass, show three bulges to the north and three to the south; the approximate drifts, in order of decreasing altitude, are given in table 3. With allowance for inevitable errors of observation, it is clear that several superimposed currents were flowing in opposite directions, the most marked being at the top and bottom. These were clearly drawn by other observers, as well as by Smith.

The visible train was wholly below the limit of 75 km given by Trowbridge for long-enduring night trains; his theory for their long visibility would presumably not apply, and we are forced back upon reflection from dust or smoke as the more probable explanation. Calculations based upon the motions of the train give approximate wind velocities at several altitudes far above the earth's surface, altitudes in general too high to be reached by sounding balloons. The motions further illustrate the complexity and diversity in direction of these winds, and the danger of theorizing on the few data so far available.

The writer is greatly indebted to H. E. Hathaway of the U. S. Weather Bureau Office at Reading, Pa., for much help in obtaining several of the observations.

TABLE 3

Altitude	Velocity of drift	Direction of drift
km.	*km/hr*	
62	121	N. to S.
47	82	S. to N.
44	30	N. to S.
42	52	S. to N.
39	38	N. to S.
29	79	S. to N.

RELATION OF SEASONAL TEMPERATURES IN THE MISSOURI AND UPPER MISSISSIPPI VALLEYS TO ANTECEDENT PRESSURE DEPARTURES IN OTHER REGIONS

By T. A. BLAIR and A. G. TOPIL

[Weather Bureau, Lincoln, Nebr.]

Although it is well known that pressure changes in various parts of the world are more or less closely related to subsequent weather changes in distant places, it is not possible in the present state of knowledge to say with certainty and without trial what widely-separated places will show a high degree of relationship. Hence, the work of finding such relations remains largely on an empirical, exploratory basis of trying out various combinations in the hope of finding some results of value, either for immediate application to forecasting or for the accumulation of data which, it may be hoped, will lead finally to some general interpretation of the interactions of the atmosphere.

During the winter of 1933–34 a large number of simple correlations of this character were calculated with funds provided by the Civil Works Administration, as has been reported by Weightman.[1] In one group of these, one element considered was the average temperature by seasons in the Missouri and upper Mississippi valleys, called district 5, computed from the records of 10 first-order Weather Bureau stations. The relations between these temperatures, and the pressures in some previous season at each of 69 stations distributed in all parts of the world, were determined separately. For the 4 seasons there were 12 correlations for each pressure station, or a total of 828 correlation coefficients for the 69 stations. A number of these were large enough to indicate a definite connection between temperatures in district 5 and previous pressures elsewhere, but none were of sufficient magnitude to have any positive forecasting value. The largest was 0.679, connecting the spring temperatures in district 5 with the pressures at Midway Island during the preceding summer, 9 months earlier. In all there were 21 coefficients greater than 0.400.

The question naturally arises whether a better result can be obtained by using two or more stations, and considering their combined relation to the temperatures in district 5. A few such calculations, using two pressure stations, have been made, and the results are set out in table 1. The method of procedure was to select 2 of the 69 stations which showed important simple correlations with the temperatures of a given season, and to calculate from these total correlations the multiple correlation coefficients, using the formula,

$$R^2_1=\frac{r^2_{12}-r^2_{13}-2r_{12}r_{13}r_{23}}{l-r^2_{23}}.$$

In this equation the r's are the simple correlation coefficients that connect pairs of the values to be correlated,

[1] R. H. Weightman, Preliminary Report on Relationship between Temperatures in the United States and Precedent Pressures outside the United States; Transactions, American Geophysical Union, 15th Annual Meeting, April 1934, Part I, pages 12, 13.